The Influence of Silvicultural Practices On The Susceptibility and Vulnerability Of Northern Rocky Mountain Forests To The Western Spruce Budworm

COMPREHENSIVE PROGRESS REPORT

APRIL 1, 1981 - MARCH 31, 1982

By CLINTON E. CARLSON, LEON J. THEROUX, and WARD W. McCAUGHEY

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1. TITLE: The Influence of Silvicultural Practices on the Susceptibility and Vulnerability of Northern Rocky Mountain Forests to the Western Spruce Budworm

2. PRINCIPAL INVESTIGATOR: Dr. Clinton E. Carlson
Research Forest Biologist
USDA, Forest Service
Intermountain Forest and Range Experiment Station
Research Work Unit 1251
Forestry Sciences Laboratory
Drawer G
Missoula, Montana 59806
Telephone: Commercial (406) 329-3533
FTS 585-3533

3. OTHER COOPERATORS INVOLVED:

   a. Mr. Ward McCaughey, Forester

   b. Mr. Leon Theroux, Biological Technician

   c. Dr. David G. Fellin, Research Entomologist

   d. Dr. Wyman Schmidt, Research Forester

4. ACTIVITY NUMBERS TO WHICH WORK IS ADDRESSED:

   a. 2.2.1 Determine relationships of site/stand characteristics and management practices to stand susceptibility and vulnerability.

   b. 2.3.1 Refine and improve stand projection model to include major budworm host types, with and without outbreak histories.

   c. 3.1.1 Determine how and to what extent WSBW damage affects forest resources and management plans.

APPROVALS

APPROVED BY:

DR. DAVID G. FELLIN, WSBW Team Leader	22 March 82 Date
DR. WYMAN SCHMIDT, Project Leader	3/26/82 Date
MR. THADD HARRINGTON Assistant Director, Intermountain Station	3/30/82 Date

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SUMMARY

Thirty-nine stands in the grand fir climax forest series were sampled according to our study plan during the summer of 1981 and seven previously established "intensive" stands were resampled. All data were keypunched, entered into our Perkin-Elmer Computer system, and have been partially analyzed. All data collected since 1979 have been utilized in analysis of stocking probability. Budworm reduced stocking probability in dry habitats but had no measurable effect in more mesic stands. Stand vulnerability to western spruce budworm (WSBW) is predictable through use of a regression model in which several site and stand variables are utilized. Stage II spring larval dispersal was not related to stand structure in the intensive stands sampled, but seemed to be a random effect. Also, Stage II larval dispersal did not appear to be related to seedling injury.

Presentations of data were made at the Western International Forest Insect Work Conference in Missoula, Montana, during March 2-4, 1982, and at the Northwest Scientific Association annual meeting in Walla Walla, Washington, during March 17 and 19, 1982. Data analysis is continuing and the project is on schedule.

INTRODUCTION

It has been suggested that silvicultural strategies can be employed to reduce tree damage caused by the western spruce budworm, *Choristoneura occidentalis* Freeman. With this concept in mind, this 5-year study was designed to:

1. Identify silvicultural strategies that will minimize the impact of WSBW (western spruce budworm) on conifer regeneration in managed forests of the Northern Rockies.

2. Provide a quantitative data base with which to make critical decisions about WSBW damage to regeneration; and

3. Improve the state-of-knowledge of the complex interactions between WSBW, site and stand conditions, environmental gradients, vegetation types, and other biotic and abiotic factors.

This comprehensive report details the progress made during April 1, 1981-March 31, 1982, and specifically relates to the research proposal to CANUSA West, "The Influence of Silvicultural Practices on the Susceptibility and Vulnerability of Northern Rocky Mountain Forests to the Western Spruce Budworm," by Clinton E. Carlson, submitted in August 1980. Objectives for this period were:

1. Measure the effect of WSBW on height growth, vigor, and crown development of established conifer reproduction between ages 5 and 15 years in various harvest systems in the grand fir climax series; and

2. Determine if past WSBW activity has adversely affected the establishment of conifer regeneration relative to various silvicultural systems.

METHODS AND DESIGN

Selection of Stands

Data were collected from conifer stands between 5 and 15 years old which resulted from previous harvest cuts in the budworm-susceptible grand fir forest climax series present in Montana (fig. 1). Four regeneration cutting systems (clearcut, shelterwood, seed tree, and selection) were studied relative to two levels of budworm infestation (none-to-light and moderate-to-heavy). Units of three sizes were selected (<5 acres, 5-50 acres, and >50 acres), and two replicates were considered. It is stands of these types that the land manager--be he federal, state, or private--is very interested in from a silvicultural perspective relative to the effect of budworm. Thus, the design implies that 48 stands would be selected and studied in 1981 (one series x two budworm levels x four cutting systems x three unit sizes x two replicates).

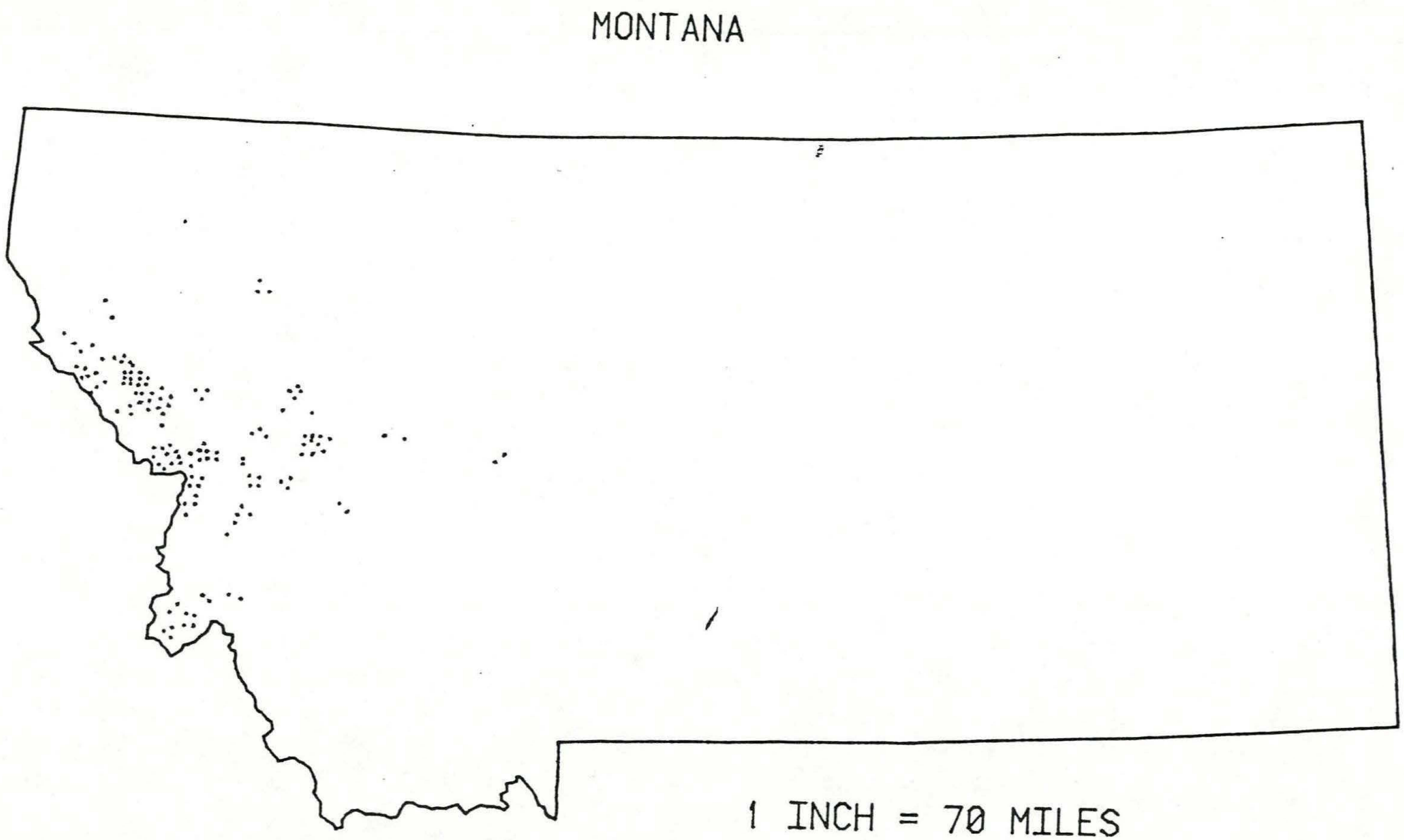

FIGURE 1 1979-1981 SAMPLE SITES

Listings of candidate stands were obtained from Forest Service Regions 1 and 4, Bureau of Indian Affairs, Bureau of Land Management, Burlington Northern, Champion International, and the State of Montana. Based on field observations that WSBW has been moderate-to-heavy for 10-15 years in the Bitterroot Range west of Missoula, we selected most of the infested study stands in that area. This area has an extensive logging history, all of the silviculture methods we propose to consider are represented, and other intrinsic site factors, such as soils, elevations, aspects, slopes, and geological histories, are reasonably similar.

Stands selected for study must have met the silvicultural standards prescribed at time of cutting. We did not want to sample stands that were hygraded, leaving only the poorest material for seed source. Rather, for example, in a seed tree cut, one would select a stand in which average or better trees were left for the seed source and reasonably good site preparation was attempted. Potential study sites were selected at random and field checked to assure that our basic criteria were met.

A summary of pertinent information for all stands sampled to date is given in table 1.

Table 1

STAND SUMMARY DATA FOR STANDS EXAMINED IN 1979

STAND	CUTSYS	ACRES	PLOTS	HABIT	ASPECT	SLOPE	PHY	PREP	SEVIDX	AGE	STOCK	ELEV	IBA	OBA
2	14	35	21	312	14	11	2	2	0.37	12	23	3700	70	110
5	14	280	23	313	3	1	5	1	0.00	10	8	4600	63	180
19	13	36	27	312	14	10	5	1	0.44	12	29	5400	6	90
20	13	56	37	281	16	43	3	1	0.71	15	54	5000	15	208
21	13	33	26	323	12	39	2	2	0.00	15	26	6500	12	68
23	11	5	11	313	28	52	2	1	0.00	15	27	5600	0	280
25	11	30	29	283	19	36	3	3	0.27	10	31	4800	0	124
26	11	29	32	521	11	45	3	3	0.71	10	77	5100	0	88
31	11	4	9	313	28	43	3	2	0.42	14	55	5400	2	112
35	11	20	21	312	8	17	2	2	0.41	14	57	5100	2	84
41	11	5	11	323	17	37	2	2	0.00	18	18	6600	0	155
54	12	11	13	283	16	31	2	2	0.38	8	53	5700	26	130
66	12	65	24	210	19	53	2	1	0.76	12	75	4000	23	95
69	12	24	19	282	15	23	2	1	0.80	10	84	5200	21	64
70	12	55	30	321	21	31	2	1	0.31	13	20	6100	35	60
73	14	51	19	293	20	39	3	1	0.38	11	100	4300	23	50
74	12	166	35	311	16	34	2	1	0.50	12	40	5700	18	130
100	14	4	7	283	7	37	3	1	0.31	13	42	4900	54	35
102	14	4	8	262	25	61	2	1	0.20	5	37	4800	8	60
124	13	31	19	262	27	36	2	2	0.63	7	26	4800	13	28
126	14	30	33	262	9	21	2	1	0.43	8	51	3800	27	73
127	11	120	28	261	28	49	2	2	0.28	17	46	4600	2	106
128	12	37	22	261	5	39	2	1	0.86	8	50	4400	19	76
129	11	43	21	281	9	36	2	3	0.61	15	23	5400	0	90
130	13	81	34	283	22	13	2	1	0.00	9	52	5600	8	147
131	13	31	20	281	21	31	2	3	0.58	15	60	5000	8	83
132	14	49	25	283	20	14	2	1	0.00	11	36	5700	48	133
133	13	5	6	283	29	11	2	1	0.38	9	33	5600	43	115
134	12	28	13	312	13	33	2	2	0.00	10	38	6500	23	105
135	13	186	55	312	15	22	2	1	0.59	8	32	3900	10	66
136	11	5	7	283	9	39	2	1	0.62	17	85	6200	6	93
137	11	2	6	262	22	55	2	1	0.53	13	83	4900	13	73
138	11	20	18	312	23	47	2	2	0.65	13	77	4900	4	132
139	12	4	7	322	26	45	2	1	0.49	13	100	5500	26	110
140	11	61	17	322	16	47	2	2	0.33	10	47	5200	1	56
141	12	7	13	311	26	46	2	1	0.67	5	76	5100	17	40
142	14	4	12	282	11	15	5	1	0.75	11	75	3600	50	50
143	11	80	46	261	18	58	2	1	0.00	18	52	4600	2	95
144	13	50	24	261	9	39	2	1	0.00	11	33	4800	11	72
145	14	50	17	261	21	42	2	1	0.65	9	5	5600	80	130
146	11	150	27	312	17	13	5	3	0.00	14	48	5300	1	120
148	14	87	23	262	17	23	2	1	0.67	10	21	4500	30	60
149	14	45	25	261	16	37	2	1	0.70	11	44	4900	15	68
150	14	5	6	261	11	31	3	1	0.55	8	33	4000	33	53
151	12	27	16	321	23	25	2	1	0.58	11	37	4300	31	30
152	14	23	20	262	25	20	2	1	0.45	13	45	4200	30	52
153	11	51	17	261	14	32	2	3	0.58	16	82	4500	0	77
154	13	5	11	261	8	35	2	1	0.51	6	9	4400	24	92

KEY:

CUTSYS = CUTTING SYSYEM

HABIT = HABITAT TYPE

ASPECT = ASPECT IN DEGREES

SLOPE = PERCENT SLOPE

PHY = PHYSIOGRAPHY

PREP = SITE PREPERATION

SEVIDX = SEVERITY INDEX

STOCK = PERCENT STOCKED

ELEV = ELEVATION

IBA = INSIDE BASAL AREA/ACRE

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Table 1 (continued)

STAND SUMMARY DATA FOR STANDS EXAMINED IN 1980

STAND	CUTSYS	ACRES	PLOTS	HABIT	ASPECT	SLOPE	PHY	PREP	SEVIDX	AGE	STOCK	ELEV	IBA	OBA
200	11	13	28	592	29	41	2	1	0.83	20	89	4100	4	64
205	12	20	25	591	4	27	3	1	0.81	20	92	3800	38	72
210	14	65	49	662	25	25	3	1	0.77	7	69	4600	59	82
215	13	30	41	691	4	39	3	1	0.00	9	65	5800	29	155
220	12	2	7	662	5	19	2	1	0.00	17	100	5400	39	65
221	14	29	16	692	11	32	3	1	0.00	13	68	5100	74	95
222	14	42	26	691	15	49	2	1	0.00	15	80	6000	23	98
223	12	4	12	691	11	24	2	1	0.00	7	100	5800	62	63
224	12	6	11	691	18	28	2	1	0.00	7	81	5600	42	125
225	12	16	18	720	12	26	2	1	0.00	8	77	5800	9	128
226	13	78	24	691	30	30	3	2	0.00	8	45	5900	3	82
227	12	4	8	670	1	48	3	1	0.62	18	100	5800	50	105
228	12	20	15	670	27	52	3	1	0.00	18	86	5800	52	65
229	11	31	25	670	12	45	2	3	0.62	13	80	5700	3	148
230	12	77	26	691	28	49	3	1	0.50	15	88	5300	57	97
231	11	12	14	691	25	38	2	3	0.00	14	57	7100	0	53
232	13	109	22	640	20	10	5	2	0.00	15	27	4500	2	80
233	13	38	14	691	24	19	3	3	0.00	14	85	5800	0	83
234	13	31	15	691	15	24	2	2	0.00	15	40	5600	7	63
235	11	4	6	625	34	59	3	3	0.00	20	100	5200	0	55
236	12	63	20	283	28	55	2	1	0.43	18	30	5300	18	48
237	12	4	7	625	2	31	3	1	0.36	16	28	5000	7	38
238	11	23	18	670	5	33	3	3	0.00	13	44	6200	0	93
239	12	67	25	691	14	28	2	2	0.00	11	56	6300	5	78
240	11	4	8	691	10	57	3	3	0.00	13	50	5000	4	75
241	11	32	20	670	29	42	3	1	0.00	14	95	5800	1	80
242	13	3	11	691	25	33	2	2	0.00	6	54	6200	7	103
243	12	8	14	691	13	27	2	1	0.65	7	64	5700	20	46
244	12	54	26	691	16	25	2	1	0.00	7	96	6100	22	98
245	13	3	10	640	29	25	3	1	0.65	18	100	4400	8	63
246	13	12	16	640	15	25	2	1	0.00	18	62	4200	10	60
247	14	58	26	691	9	49	2	1	0.76	20	100	5400	84	57
248	11	90	25	662	29	30	3	3	0.00	15	52	5000	0	92
249	14	12	13	670	9	35	3	1	0.23	14	92	5000	82	58
250	11	3	5	692	17	27	3	3	0.00	13	80	6200	0	75
251	11	4	8	691	16	45	2	3	0.00	9	0	6500	0	80
252	11	88	23	625	9	41	3	3	0.80	6	60	4800	0	68
253	13	80	22	624	11	11	3	3	0.75	6	63	4800	0	60
254	11	61	22	625	32	27	3	3	0.44	10	81	5400	0	48
255	13	69	21	691	20	17	2	2	0.00	13	47	5000	3	48
256	11	65	18	691	18	39	2	1	0.00	12	50	6200	0	108
257	14	16	9	670	10	57	3	1	0.51	18	100	6000	42	85
258	14	5	8	691	7	52	3	1	0.59	6	50	5500	11	93
259	11	76	25	691	23	41	3	3	0.00	13	76	6100	0	97
260	13	18	17	662	27	48	2	1	0.00	10	94	5800	25	53
261	14	14	12	691	9	48	2	1	0.00	19	83	5400	38	65
262	14	10	9	670	13	39	3	1	0.00	19	100	5400	50	63
263	11	4	8	691	24	41	3	3	0.49	16	0	6500	1	76

KEY:

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Table 1 (continued)

STAND SUMMARY DATA FOR STANDS EXAMINED IN 1981

STAND	CUTSYS	ACRES	PLOTS	HABIT	ASPECT	SLOPE	PHY	PREP	SEVIDX	AGE	STOCK	ELEV	IBA	OBA
300	11	40	16	740	5	47	3	3	0.49	12	56	5500	0	105
301	14	12	14	523	19	24	3	2	0.34	11	78	4700	27	110
302	12	30	16	510	8	23	3	1	0.59	14	100	4600	44	76
303	14	25	14	283	10	11	3	2	0.61	5	42	6000	51	105
304	14	25	18	510	8	19	3	2	0.49	7	66	5300	35	75
305	11	80	27	591	26	42	3	3	0.00	11	51	5000	0	51
306	11	7	11	293	28	46	3	3	0.73	9	72	4500	0	88
307	11	4	9	262	9	51	3	2	0.49	9	88	4200	0	80
308	11	2	9	591	5	43	3	2	0.64	20	44	4100	0	100
309	11	40	47	531	16	38	3	3	0.53	16	61	4600	0	78
310	11	5	9	591	22	51	3	1	0.61	16	77	4800	0	100
311	11	79	35	591	25	46	3	3	0.62	18	61	4400	0	90
312	14	13	11	591	2	43	3	1	0.00	19	81	4800	50	108
313	11	3	8	521	14	47	3	3	0.00	19	75	4800	0	80
314	11	4	7	531	9	26	3	3	0.75	10	71	4800	0	78
315	13	18	15	621	9	38	3	2	0.49	6	46	5200	41	116
316	11	6	12	522	24	50	3	3	0.87	10	66	4300	0	115
317	11	68	30	510	2	3	5	3	0.60	14	66	3200	0	86
318	11	25	16	522	20	45	3	3	0.63	14	75	4500	0	94
319	14	5	9	510	4	50	3	1	0.47	6	60	4900	32	75
320	12	7	10	510	2	42	3	1	0.52	6	50	4800	33	158
321	13	23	17	510	7	40	3	1	0.73	7	86	5100	17	55
322	13	40	18	521	10	40	3	1	0.45	6	83	4800	18	101
323	13	12	14	320	24	39	3	1	0.82	14	64	4000	13	98
324	12	9	12	323	17	51	2	3	0.00	6	33	4200	12	113
325	12	32	29	523	18	6	3	2	0.00	7	89	4900	24	122
326	14	25	16	531	6	1	5	1	0.85	22	62	3300	5	58
327	14	57	23	510	12	27	3	2	0.72	8	62	4800	26	56
328	13	5	9	510	21	49	2	3	0.36	7	11	3600	6	103
329	11	116	30	510	23	46	3	3	0.23	10	73	5200	0	86
330	13	7	8	510	15	48	3	1	0.77	9	100	4900	34	58
331	13	71	26	510	9	30	5	3	0.00	12	76	4000	4	113
332	12	5	9	521	14	27	3	1	0.00	6	44	3400	63	70
333	14	61	24	523	23	9	5	1	0.56	6	83	3200	42	146
334	13	84	27	591	22	14	3	3	0.00	12	85	3500	1	60
335	11	1	7	510	5	45	3	1	0.30	6	85	4400	4	130
336	14	4	7	593	31	39	3	1	0.09	19	100	4100	40	33
337	11	6	11	592	19	45	3	1	0.18	15	100	5000	0	93
338	13	10	9	510	27	65	3	1	0.00	14	66	5000	47	60

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Field Sampling

ADJACENT STANDS

The residual stand adjacent to the selected study stand was characterized. About five to seven variable-radius plots were established, and species composition, basal area, crown classes, crown ratios, heights, and diameters were recorded. All WSBW host trees within the variable plot were rated for defoliation, using the three-crown strata system agreed upon at the Lubrecht meeting.[1] The crown is visually separated into lower, middle, and upper. Each portion is then rated for WSBW defoliation and coded as follows:

Description	Code
No defoliation	0
Light defoliation	1
Moderate defoliation	2
Severe defoliation	3

These are subjective classes and reflect defoliation over a period of years--1 to 7 or 8--depending on the situation.

[1]CANUSA meeting held at Lubrecht Experimental Forest in western Montana, May 16, 1979.

It is important that the history of WSBW in these adjacent stands be known. We assume that if WSBW had been intense enough to have caused a detrimental effect in the study stands, it also would have been adequately intense to have caused an observable effect on radial stem growth of residual host trees in the adjacent stands. We have collected and analyzed preliminary data that indicate, indeed, that this is the case. Therefore, from infested stands, two increment cores from each of three defoliated host trees and three nonhost trees were extracted, placed in plastic straws to prevent dehydration, and transferred to our laboratory where annual radial increment was measured and recorded. In noninfested stands, the same procedure was followed.

SAMPLING WITHIN CUTTING UNITS

Plots 1/300 acre in size were established along parallel transects that encounter most of the recognized site variability. Stage (1973) used plots of this size in similar studies and found them adequate, and National Forest management routinely uses 1/300-acre plots in silvicultural examinations. Sampling error for a given variable within a matrix cell[2] should be within the confidence interval:

$$\bar{x} \pm T_{.05}\,(SE_{\bar{x}}), \text{ such that:}$$

$$\frac{T_{.05}\,(SE_{\bar{x}})}{\bar{x}} \leq .20$$

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[2]A matrix cell is defined as any single combination of the stand selection criteria.

A number of variables known to influence conifer regeneration establishment, survival, and growth were measured at each plot. It is important that this study relate to and be understood by forest land managers. Therefore, many of the variables measured within each stand and plot are those variables routinely measured in stand examinations by foresters and silviculturists.[3]

Each plot was unique as the sampling unit and all variables were quantified. Thus, the stand selection criteria were quantified and recorded as follows:

a. Forest climax series - habitat type

b. Budworm damage rating given to residual stand (Bousfield[4]) and increment analysis as described above

c. Cutting system - Basal area of residual stand was estimated with a 10 BAF prism

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[3]See "Field Instructions, Stand Examination and Forest Inventory." Stand Examination Handbook FSH 2409.21, R1, Chapter 300. April 1978. USDA, Northern Region. 113 p.

[4]The actual method was determined at a joint field meeting of the Moscow and Missoula INT Laboratories. Personal communication with Wayne Bousfield, FPM, Region 1 Forest Service, Missoula, MT.

d. Cutting unit size - acres

Intrinsic site variables measured and recorded at each plot were:

a. Aspect; degrees

b. Slope percent

c. Physiography; ridgetop, dry slope, moist slope, stream bottom, flat or bench

d. Site preparation - none, mechanical or burned

e. Relative position of suspected seed and WSBW source by bearing, distance, and angle from plot center.

It is standard practice in National Forest management to consider the dominant two established seedlings on each 1/300-acre plot as "management trees," or those seedlings most likely to become the preferred crop trees. Therefore, the following data, known to be silviculturally important, were collected from the two tallest established trees on each plot and recorded:[5]

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[5]Details of these measured variables are presented in our 1980 continuing research proposal to CANUSA West, "The Influence of Silvicultural Practices on the Susceptibility and Vulnerability of Northern Rocky Mountain Forests to the Western Spruce Budworm."

a. Height from ground line to the bud scar of the previous year, in 0.1 foot

b. Species

c. Age - sample trees were cut at ground line and annual rings tallied

d. Dead or alive

e. Established or nonestablished

f. Vigor - height growth during past 5 years, 0.1 foot

g. Advanced growth or subsequent

h. Planted or natural

i. Crown position

j. Crown width, 0.1 foot

k. Crown length, 0.1 foot

ℓ. D.b.h., inches

m. Growth of current year - 0.1 foot

It was also important to assess the relationship of budworm to nonmanagement trees, or those seedlings that would not be carried through a rotation. Does WSBW preferentially damage intermediate crown classes or the dominants, or is there no difference? Therefore, all conifer seedlings, other than the two tallest, were tallied, and the following information was recorded:

a. Species

b. Crown position

c. Height to nearest 0.1 foot

d. Growth of current year - 0.1 foot

The incidence of budworm defoliation on regeneration is an indication of the relative influence of silvicultural system on budworm susceptibility and vulnerability of management and nonmanagement regeneration. Damage data provide direct evidence of the feeding preference of budworm and the responses of seedlings to budworm pressure. Budworm feeds differently on western larch than on other conifer hosts; therefore, assessment techniques differ. The following sampling methods developed and tested in 1978-79 were utilized to assess current WSBW damage on host seedlings.

a. Douglas-fir, grand fir, subalpine fir, and Engelmann spruce--tallest (management seedlings)

The crowns were visually separated into three equal parts: upper, middle, and lower. A maximum of six shoots within each crown level were evaluated for current and previous WSBW defoliation and rated as follows:

Percent Defoliation	Code
0	0
1-25	1
26-50	2
51-75	3
76-99	4
100	5

Shoots were selected about equally around the crown, and percent defoliation were recorded for both current and previous years. Data for each shoot were recorded. A mean index and proportion damaged were then computed and recorded for each tree.

b. Western larch management seedlings

Fascicular damage. Each tree crown was visually separated into three portions. Within each portion, 33 dwarf shoots (fascicles) were observed, and the number of fascicles with WSBW feeding evidence was recorded. An average for the tree was derived and entered.

Lateral shoots. Ten current-year lateral shoots from upper crown were examined and the number of shoots fitting each of the following criteria was recorded:

	Type of Damage	Code
a.	No damage	0
b.	Needle-feeding only	1
c.	External shoot-mining	2
d.	Severed shoots	3

In all cases, only the most severe type of damage was recorded.

Terminal leader. Damage to terminal leaders was recorded on Field Sheets 4 and 1, as follows:

	Type of Damage	Code
a.	No damage	0
b.	Needle-feeding only	1
c.	External shoot-mining	2
d.	Severed shoots	3

c. Excess seedlings (established and nonestablished), all host species

The entire seedling was subjectively rated for defoliation, coded, and recorded on Field Sheet 1, as follows:

Defoliation	Code
0	0
1-25%	1
26-50%	2
51-75%	3
76-99%	4
100%	5

It is recognized that agents other than budworm may be responsible for seedling damage; the following general damage codes were entered:

	Damage Agent	Code
a.	Budworm	0
b.	Weather	1
c.	Animal	2
d.	Other insect	3
e.	Disease	4
f.	Healthy	5

Intensive versus Extensive Sites

The major effort of this research was to visit and characterize as many different stands as possible within given funding restraints. Therefore, most stands were observed only once--they are the "extensive" stands. However, it will be of considerable interest to annually remeasure plots established in certain stands. These are termed the "intensive" sites. Data from these sites will be used to calibrate growth data from the extensive stands.[6]

By 1980, seven intensive sites had been selected and sampled. These sites were resampled in 1981. Data were collected in exactly the same manner as for the extensive sites except that the management trees, because they will be followed in future years, were not cut for aging. Instead, age was estimated by the number of branch whorls present.

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[6] A more detailed description of the relationship of intensive to extensive sites is given in "Interim Report to CANUSA West" by C. E. Carlson, Jan. 1981.

Western Spruce Budworm Population Sampling

Estimates of WSBW larval populations and defoliation were made at 12 locations according to CANUSA West minimum standards. These locations were:

1. All intensive sites (7)
2. All study sites of Shearer and Tiernan[7] (4)
3. Lubrecht, a previous site selected by Dr. David Fellin.

Collection sites are listed in table 2. The studies of Tiernan, Shearer, and Carlson were conducted under a team concept at the Forestry Sciences Laboratory in Missoula; the collection of larval and defoliation data for all studies was assigned to Carlson.

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[7] R. C. Shearer and C. F. J. Tiernan. 1980. Assess effects of WSBW feeding and defoliation on cone and seed production within the Northern Rocky Mountains. Research Proposal to CANUSA West.

Table 2.--1981 sites for larval population and defoliation estimates

Intensive Sites

Unit number	Location name
126	Valley Creek #1
127	Blue Mountain
135	Chamberlain Creek
200	First Creek
205	Second Creek
210	Valley Creek #2
215	Union Peak

Fellin's Site

Unit number	Location name
147	Lubrecht

Cone and Seed Sites

Unit number	Location name
220	W. Fork Lolo Creek
107	Ashby Creek
116	Spring Creek
141	Richmond Ridge

At each site, CANUSA minimum standards were followed:

1. Three plots previously established at each site and consisting of three tagged WSBW host trees of dominant or codominant status were resampled.

2. During early spring, when WSBW larvae were judged to be at Instar IV, four branches were cut from midcrown of each tree. The number of WSBW larvae per 100 buds was counted and recorded.

3. In late fall, when all WSBW feeding had ceased for the season, defoliation was estimated. The crown of each tree was conceptually divided into thirds, and percent defoliation was estimated in 5-percent increments for current and past defoliation and recorded. Then four 70 cm branches were collected from midcrown of each tree and represented the four cardinal directions. Twenty-five current shoots from the apical 40 cm of each shoot were rated for defoliation as follows:

Defoliation Class	Code
0	0
1-25%	1
26-50%	2
51-75%	3
76-99%	4
100%	5

All data were entered into an electronic data file on our Perkin-Elmer Computer system.

Data Analysis

The null hypotheses being tested are:

1. WSBW does not influence conifer regeneration establishment

2. WSBW does not influence conifer regeneration growth

3. WSBW defoliation is not different on different species

4. Regeneration cutting system does not affect budworm activity

5. Unit size is not related to budworm damage on regeneration.

Simple and multiple regression and nonparametric techniques are being utilized to analyze the data. Independent variables include forest climax series, budworm infestation level, residual basal area, unit size, and distance to seed source. Dependent variables will include seedling density, probability of stocking, and damage. Covariates in the analysis include the intrinsic site variables such as slope, aspect, physiography, etc. Specific models are presented in RESULTS AND PROGRESS.

RESULTS AND PROGRESS

This continuing study was originally conceived to collect and analyze regeneration data from three forest series: Douglas-fir, subalpine fir, and grand fir. There are four main functional aspects to such a study once it is funded. They are:

1. Collect and record field data

2. Enter data on punch cards, establish computer files, correct and edit data

3. Analyze and interpret data

4. Publish and/or report results

These functional aspects overlap forest series in our study because each series was dealt with in a separate, successive year: Douglas-fir in 1979, subalpine fir in 1980, and grand fir in 1981. For data collected in a given year, it has taken us until late December to read the increment cores, keypunch all data, and establish the data files. Data analysis then is done during spring of the following year. This progress report deals with <u>analysis</u> of data collected in 1979 from the Douglas-fir series, in 1980 from the subalpine fir series, and 1981 from the grand fir series and <u>status</u> of grand fir series data. Specifically, this report deals with preliminary analysis of the influence of WSBW on probability of stocking and the relationship of past WSBW outbreaks to specific stand conditions.

Furthermore, we present current results of the relationship of Larval II dispersal to stand conditions. Even though CANUSA elected to not fund Dr. Fellin's dispersal work at our intensive sites in 1980 and 1981, we believed that the data would be important to our stocking and growth work. Therefore, at our request, the Intermountain Station funded the dispersal work in 1980-81.

WSBW and Probability of Stocking

Budworm significantly reduced stocking probability in dry Douglas-fir, dry subalpine fir, and moderate subalpine fir habitat types.[8] No effect was observed in moist Douglas-fir; warm, moist grand fir/subalpine fir/cedar; and cold, moist subalpine fir habitat types. The experimental units for the stocking analyses were the 1/300-acre plots. A plot was considered stocked if it contained at least one established, natural conifer seedling that came into existence since the harvest. The seedling could be of any species. Thus, a plot could be either stocked or nonstocked. For reasons described by Hamilton (1974), a logistic model was used to fit the dichotomous-dependent stocking variable to a set of independent predictor variables. The model has the general form:

$$\hat{P} = \left\{1 + \text{EXP}\left[-\left(B_0 + B_1X_1 \ldots + B_nX_n\right)\right]\right\}^{-1}$$

A computer program named RISK (Hamilton 1974) was used to develop the models. Because of program limitations in which the number of variables entering the analysis is contrained, and because some very real differences were observed between the habitat groups, separate models were developed for each of the six groups. Initially, independent variables were screened through discriminant analysis; the models were then refined using RISK. All data collected to date (1979, 1980, 1981) were used in the analyses.

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[8]See appendix 1 for a description of habitat type groupings. Groupings are based on similarities in general moisture and thermal properties.

For the purpose of this report, only two of the models are discussed; one for the dry Douglas-fir group represented by 592 plots, and one for the cold subalpine fir group in which 183 plots were observed. The model for dry Douglas-fir habitats is shown in table 3. The sign of the coefficient indicates the general relationship of an independent variable to the probability that a plot would be stocked. The effect of WSBW is represented by hazard index which was defined in our 1981 progress report (Carlson and McCaughey [in press]). For dry Douglas-fir habitats, increasing hazard index resulted in decreased probability of stocking. Graphically the model is presented in figure 2. Plot basal area, acres, and elevation were held constant at their respective mean values of 18.95 square feet per acre, 64.29 acres, and 4,751 feet mean sea level. One curve was plotted for each of the slope and hazard index combinations when slope is limited to 0 and 0.4 and hazard index is limited to 0 and 4. A hazard index of 0 implies no WSBW influence, and 4 implies the most severe condition possible. The slope-aspect terms were suggested by Stage (1976). The data then are plotted against aspect. Probability of stocking always is relatively low, and severe WSBW reduces stocking by as much as 33 percent.

Probably the WSBW causes this effect by reducing cone and seed numbers at and subsequent to the harvest cut. We have other data that show that established seedlings seldom are defoliated significantly by the insect, indicating that stocking is not affected by direct feeding on seedlings.

Table 3

REGRESSION MODEL FOR PROBABILITY OF STOCKING IN DRY DF HABITAT TYPES

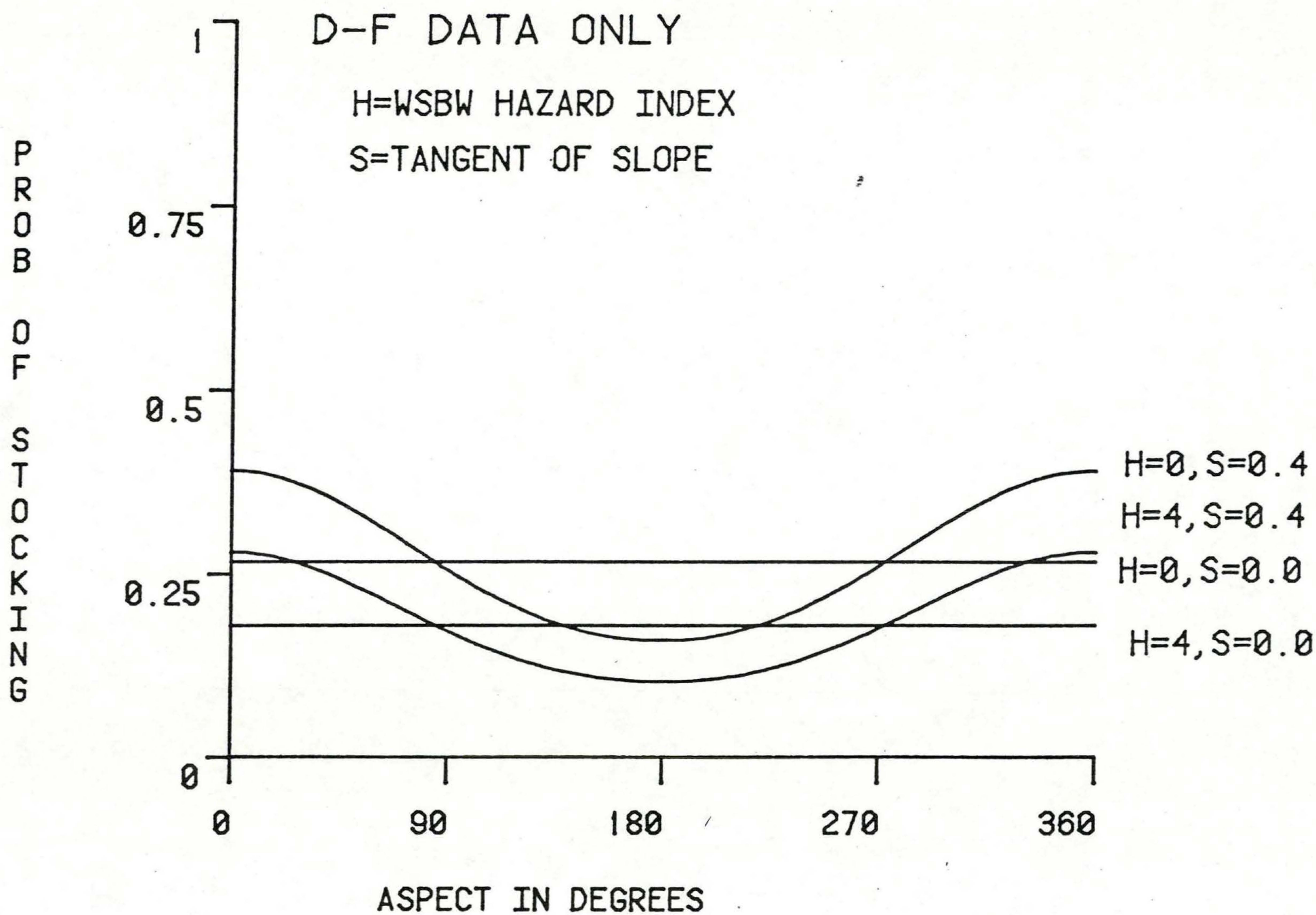
Y=(1+EXP(-(A+B1X1+B2X2....+BNXN)))^-1

VARIABLE	COEFFICIENT
PLOT BASAL AREA	-5.7092E-03
ACRES	-4.9865E-03
SLOPE TANGENT	-1.1191E-01
SLOPE*SIN(ASPECT)	-4.4987E-02
SLOPE*COS(ASPECT)	+1.5296E+00
ELEVATION	-6.8675E-02
HAZARD INDEX	-1.2571E-01
CONSTANT	+2.6793E+00

Figure 2

INFLUENCE OF WSBW, ASPECT, AND SLOPE ON PROBABILITY OF STOCKING IN DRY DOUGLAS-FIR HABITAT TYPES IN WESTERN MONTANA. 1979-1981 DATA

2-17-82



In contrast to the dry Douglas-fir habitats, no effect of WSBW was found in the cold subalpine fir habitats. The regression model is shown in table 4. Type of site preparation and interactions between age-slope and age-aspect-slope were important predictors for the model.

Effects of WSBW on stocking probability undoubtedly are influenced by the species diversity expected in the habitat groups. Douglas-fir and ponderosa pine are the predominant conifers in the dry Douglas-fir habitats, whereas up to six or more conifer species often are found in the moister groups such as the cold subalpine fir. This greater species diversity (more nonhost) in the moister habitat groups, along with better microsite conditions for seedling establishment, likely override any effect that WSBW may have on cone and seed production in the host species.

Probability of stocking was much higher in the cold, wet subalpine fir habitat group. The influence of age (time since harvest), slope, and aspect is readily seen in figure 3. Stocking probability approaches 0.90 on north-facing slopes of 60 percent at age = 20 years. Contrast this to the 0.35 probability of stocking observed in figure 2.

Table 4

REGRESSION MODEL FOR PROBABILITY OF STOCKING IN COLD SUBALPINE FIR HABITAT TYPES

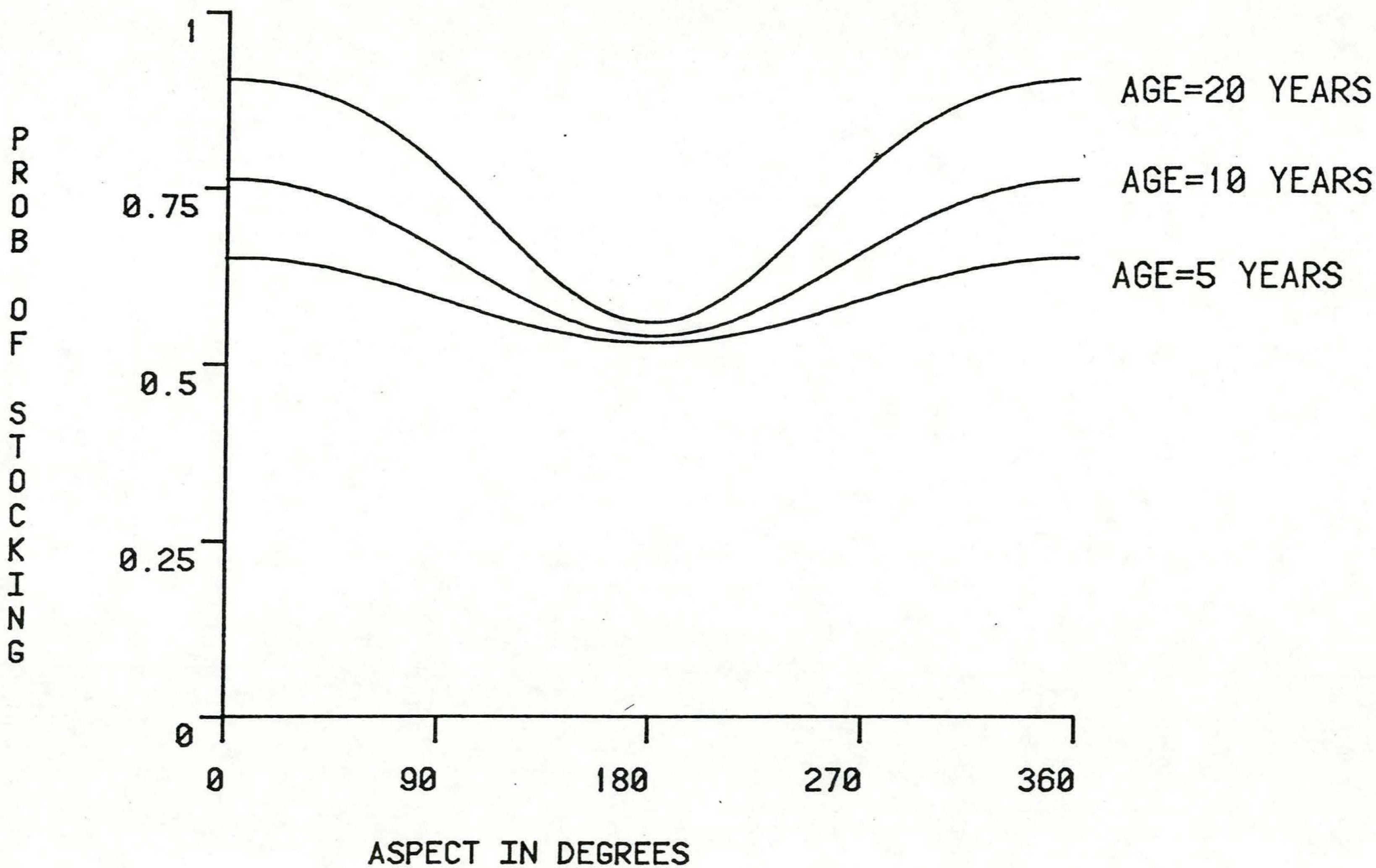
Y=(1+EXP(-(A+B1X1+B2X2+.....BNXN)))^-1

VARIABLE	COEFFICIENT
PLOT BASAL AREA	-1.9284E-02
NO SITE PREP	+2.8692E-01
MECHANICAL SITE PREP	+1.2456E+00
AGE-SLOPE INTERACTION	+7.4952E-02
SLOPE-ASPECT-AGE INTER.	+6.4917E-02
CONSTANT	-7.5688E-01

2-22-82

Figure 3

INFLUENCE OF AGE AND ASPECT ON PROBABILITY OF STOCKING
IN COLD, WET SUBALPINE FIR HABITAT TYPES. 1979-1981 DATA
SITE PREP=MECHANICAL, SLOPE=0.60 2-17-82



Past WSBW and Stand Conditions

In a recent publication we described a method to date and characterize past WSBW activity through use of increment core analyses (Carlson and McCaughey 1982). Cores are collected at breast height from at least three pairs of dominant and codominant host/nonhost trees in uncut, mature stands. Mean incremental growth is computed separately for host and nonhost, squared, accumulated, and plotted from a base time. Deflections of the host curve relative to the nonhost indicate periods of WSBW activity. The severity of the infestation is indexed by ratio of actual growth to expected growth subtracted from 1 during the infestation period (fig. 4). This index is called "severity index."

Through regression analysis we found that severity index increased as stand conditions became more favorable to WSBW. The model was developed for data collected in 96 stands located in the Douglas-fir and subalpine fir habitat groups; the model is shown in table 5. Severity index decreased with increasing elevation and with the more mesic habitats (fig. 5), but increased as the proportion of host in the stand increased (fig. 6) and as the slope increased (fig. 7).

Figure 4

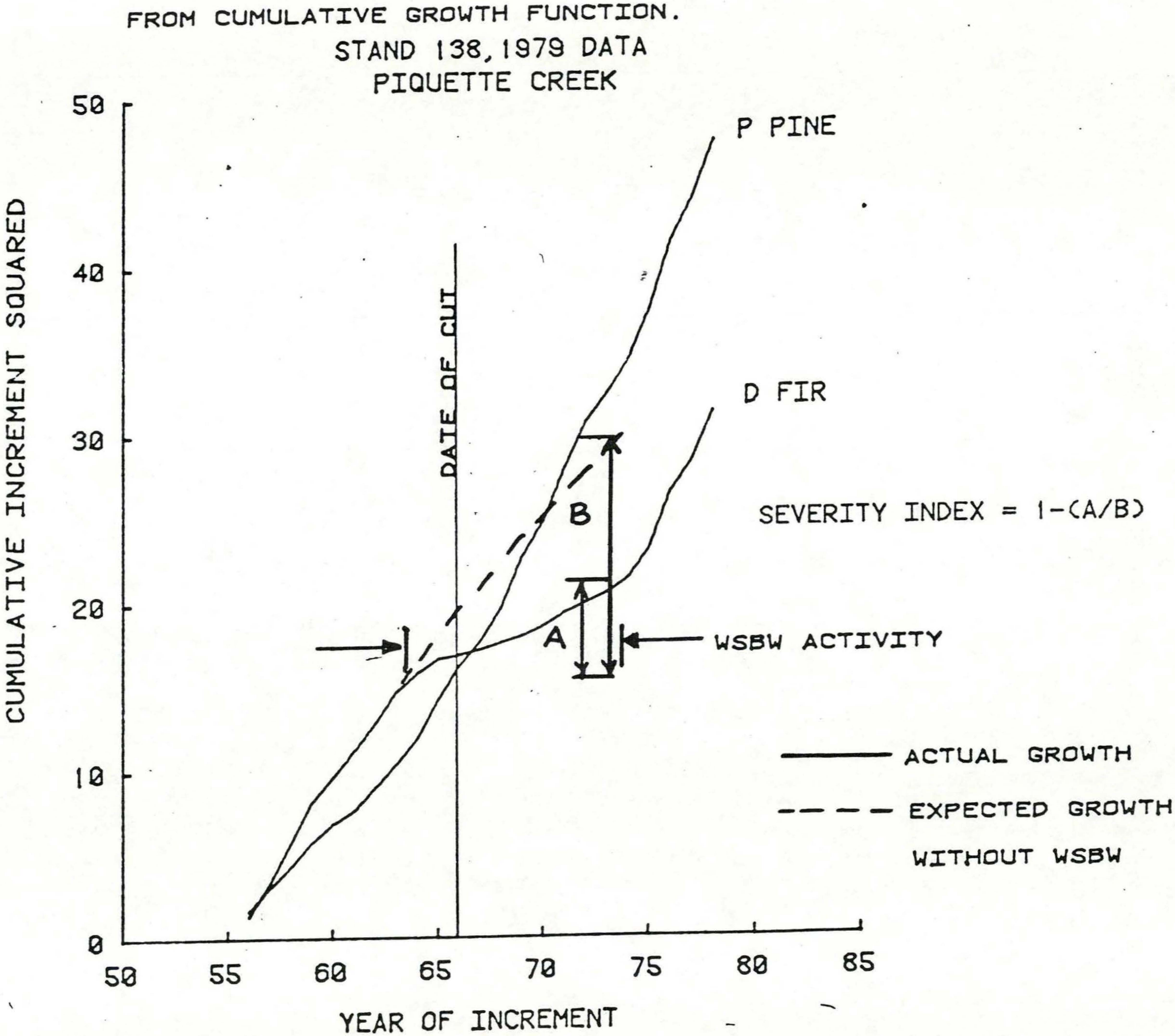

FROM CUMULATIVE GROWTH FUNCTION.
STAND 138, 1979 DATA
PIQUETTE CREEK
CUMULATIVE INCREMENT SQUARED
YEAR OF INCREMENT
P PINE
D FIR
DATE OF CUT
B
A
SEVERITY INDEX = 1-(A/B)
WSBW ACTIVITY
ACTUAL GROWTH
EXPECTED GROWTH
WITHOUT WSBW
0
10
20
30
40
50
50
55
60
65
70
75
80
85

Table 5

REGRESSION MODEL FOR SEVERITY INDEX

Y=A+B1X1+B2X2+.....BNXN

VARIABLE	COEFFICIENT
ELEVATION	-1.5124E-04
HOST RATIO	+2.8013E-01
SLOPE TANGENT	+1.2292E-01
DRY DOUG FIR HABTYPE	+2.1774E-03
MOIST DOUG FIR HABTYPE	+4.9557E-02
DRY SAF HABTYPE	-1.2249E-01
MOD SAF HABTYPE	-1.4252E-01
CONSTANT	+8.9822E-01

2-22-82

Figure 5

INFLUENCE OF ELEVATION AND HABITAT TYPE ON SEVERITY INDEX

1979-1980 DATA

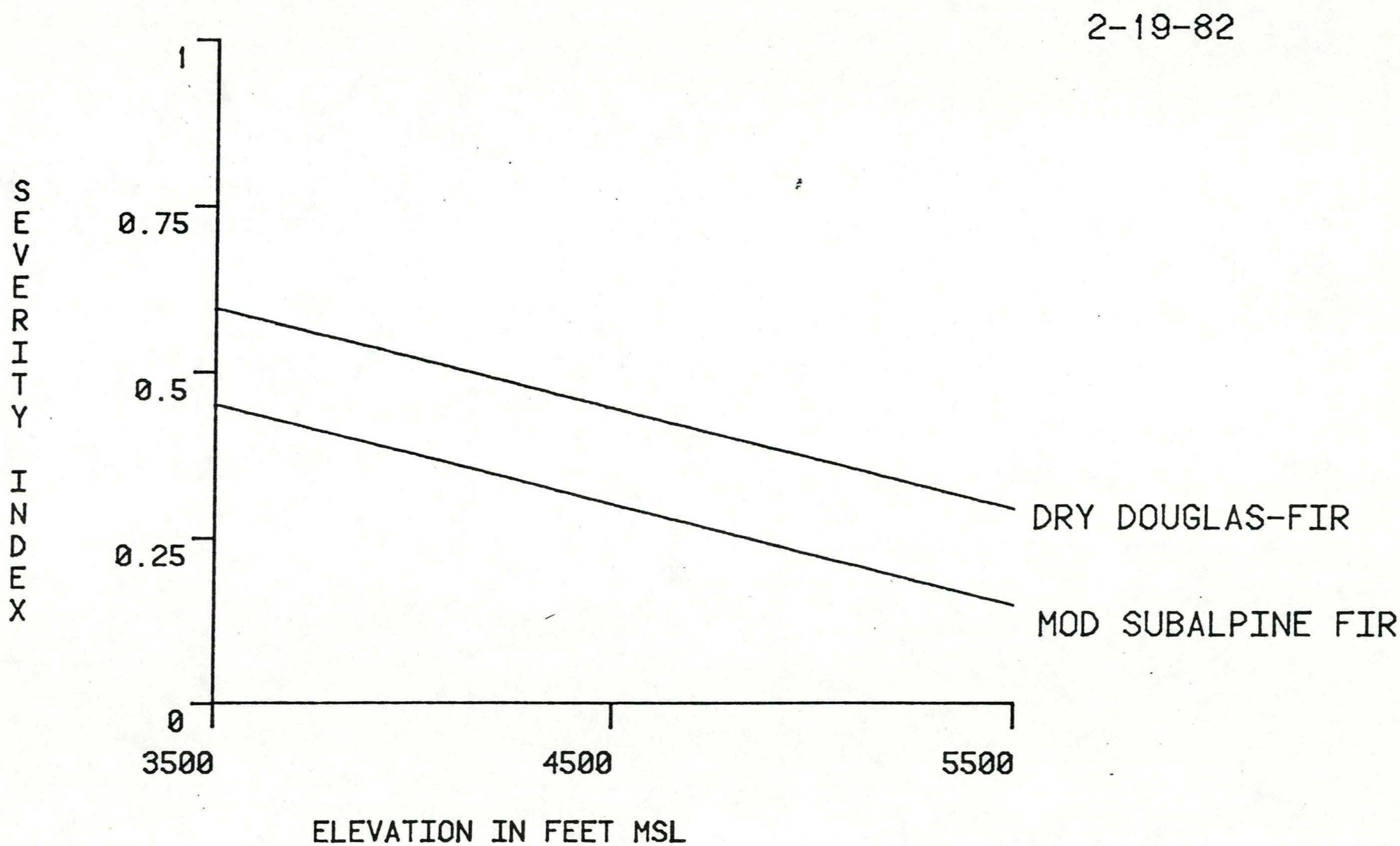


Figure 6

INFLUENCE OF HOST BASAL AREA RATIO AND HABITAT TYPE ON SEVERITY INDEX. 1979-1981 DATA

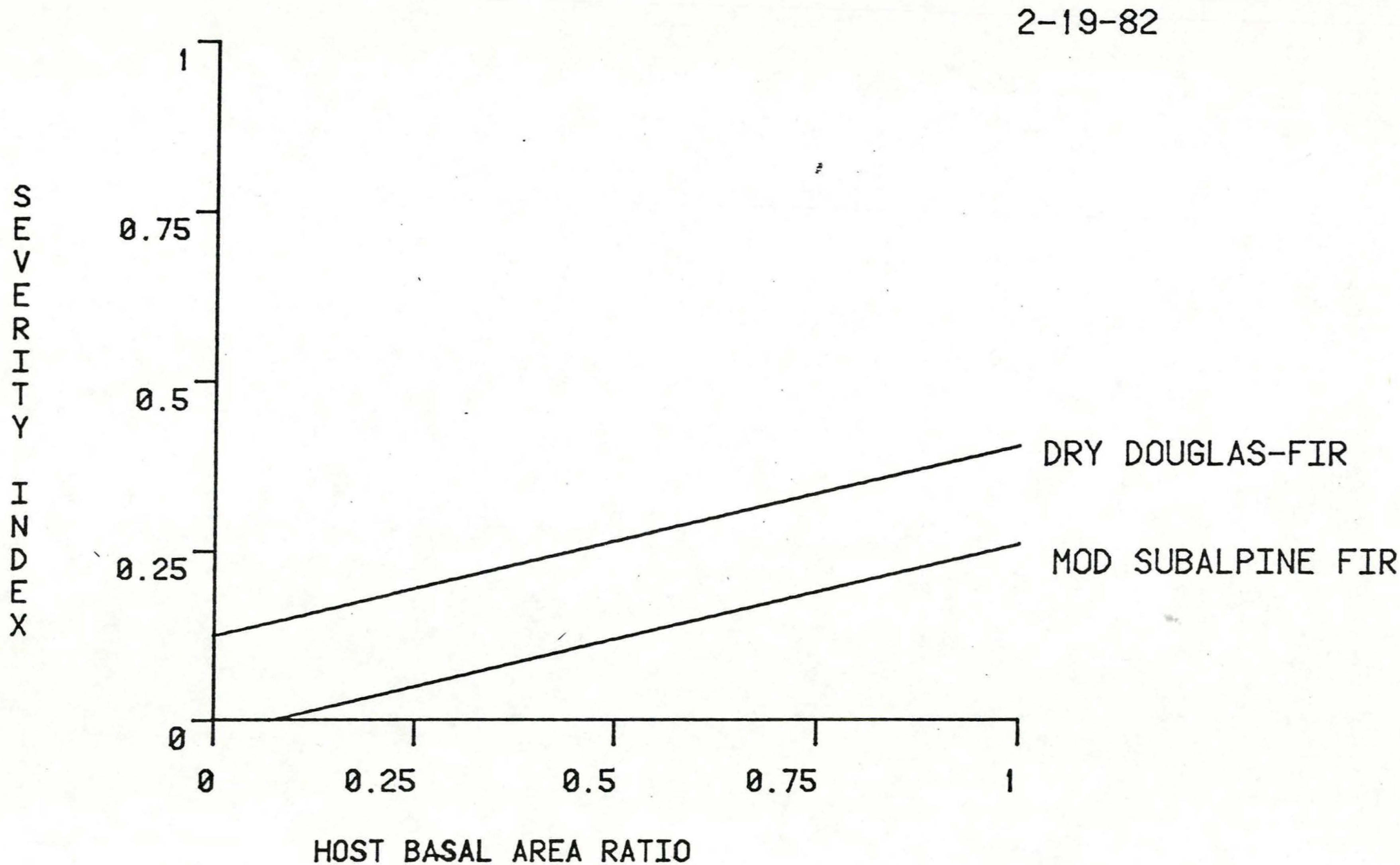
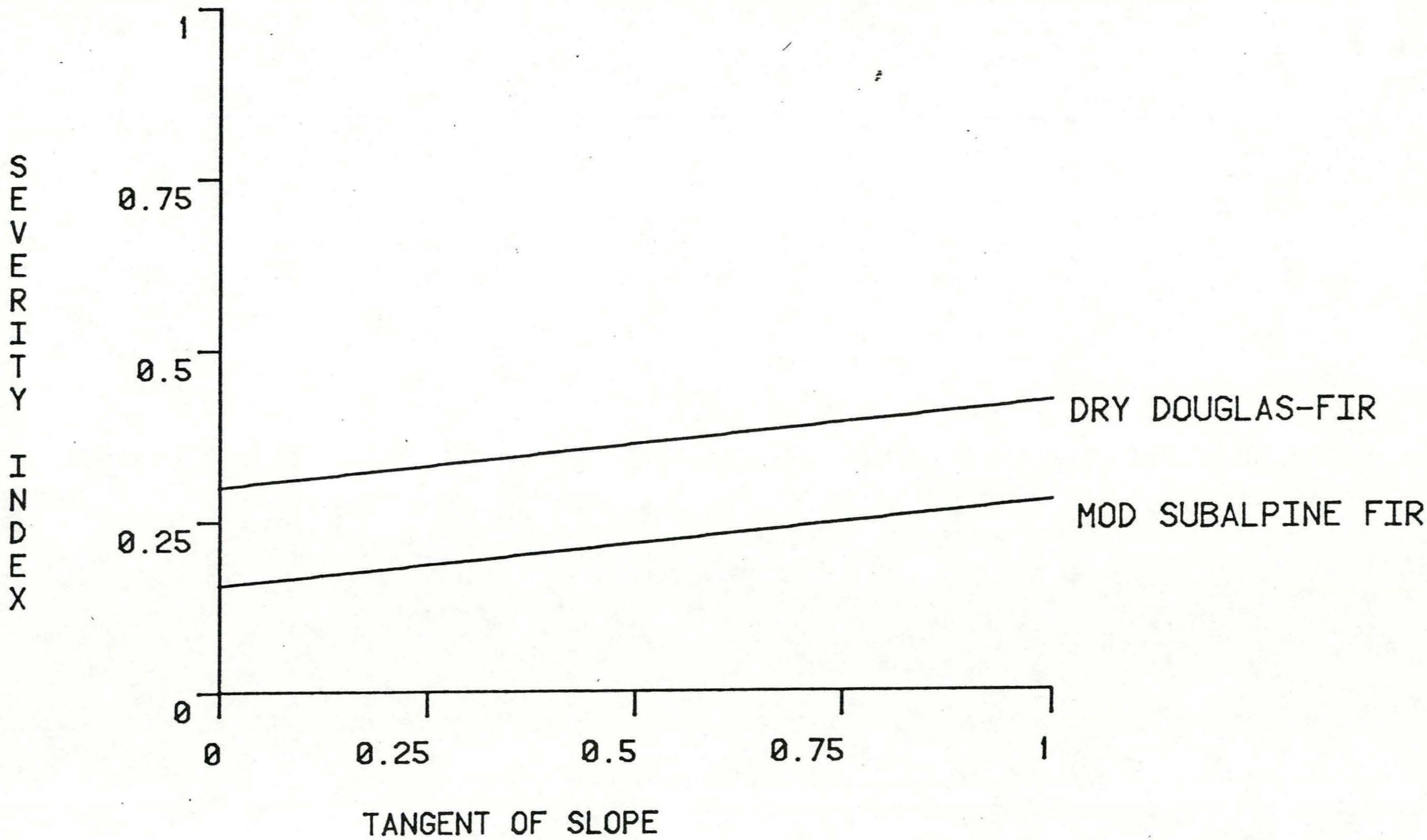


Figure 7

INFLUENCE OF SLOPE AND HABITAT TYPE ON SEVERITY INDEX

1979-1981 DATA

2-19-82



In figures 5-7, variables not displayed were held constant at their mean values. For example, in figure 7, host ratio was constant at 0.7128 and elevation was constant at 5,289 feet MSL. The most severe WSBW impact on radial growth can be expected in stands in dry Douglas-fir habitat types at low elevation (3,500 feet MSL) and steep slopes (100 percent) where the stand is pure host, such as all Douglas-fir (fig. 8).

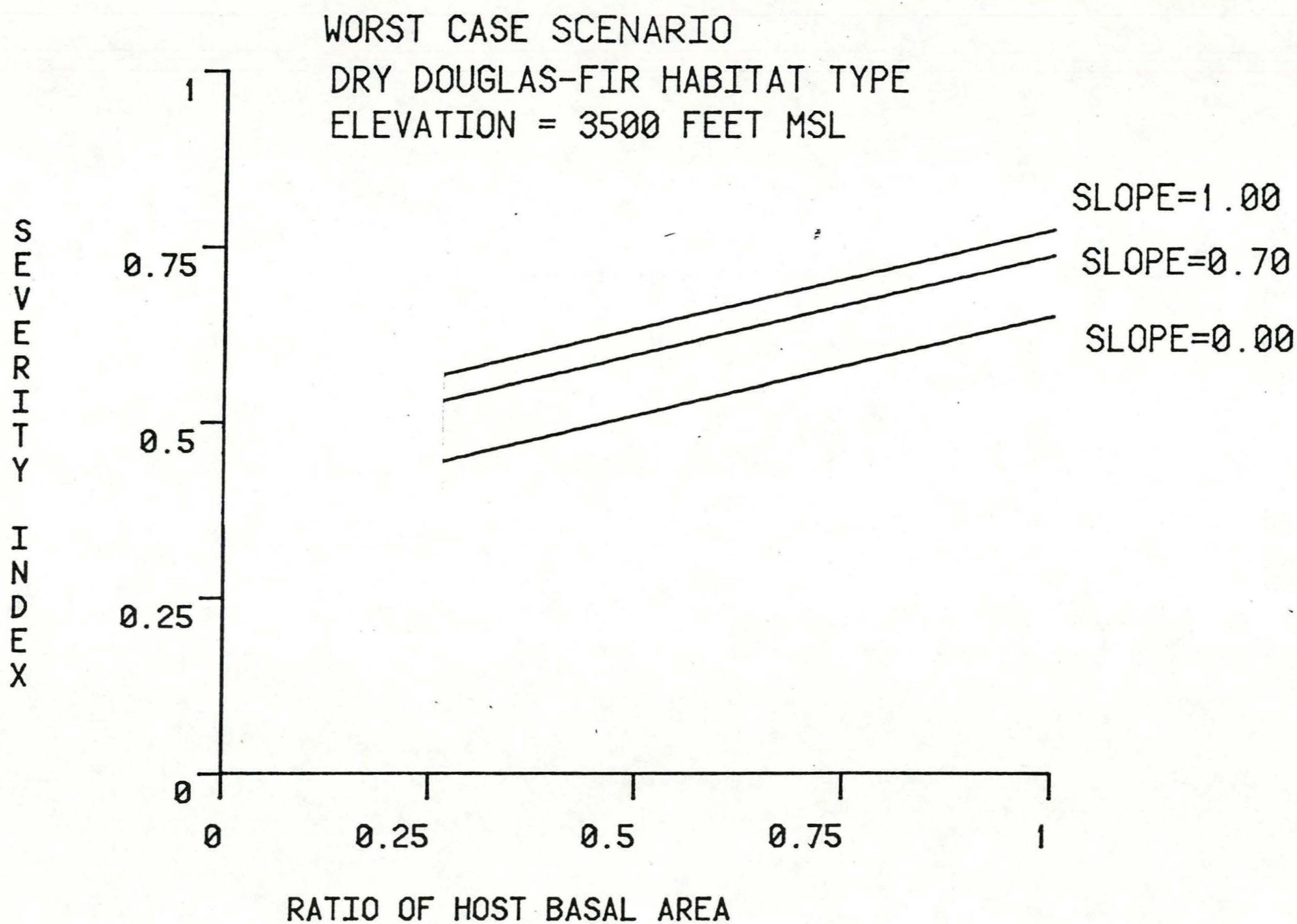
This model for predicting severity index can be interpreted as a fair approximation of stand vulnerability to WSBW. Vulnerability usually is interpreted as propensity to sustain damage once a stand is infested. The coefficient of determination (R^2) for our model was 0.37, a rather mediocre value. However, in consideration of the types of variability entering such a model (stand genetics, WSBW populations, and many others), perhaps the 0.37 figure is not too bad.

Mature stands in which severity indexes are high tend to be associated with young stands in which probability of stocking is reduced by WSBW; this supports the contention that we are measuring a real effect and that we have not created a statistical artifact. It appears that we have the basis for a hazard rating system that could be used to map existing stands especially vulnerable to WSBW and to predict potential regeneration problems. We are continuing work along this line.

FIGURE 8

INFLUENCE OF HOST BASAL AREA RATIO AND SLOPE ON SEVERITY INDEX. 1979-1981 DATA

2-19-82



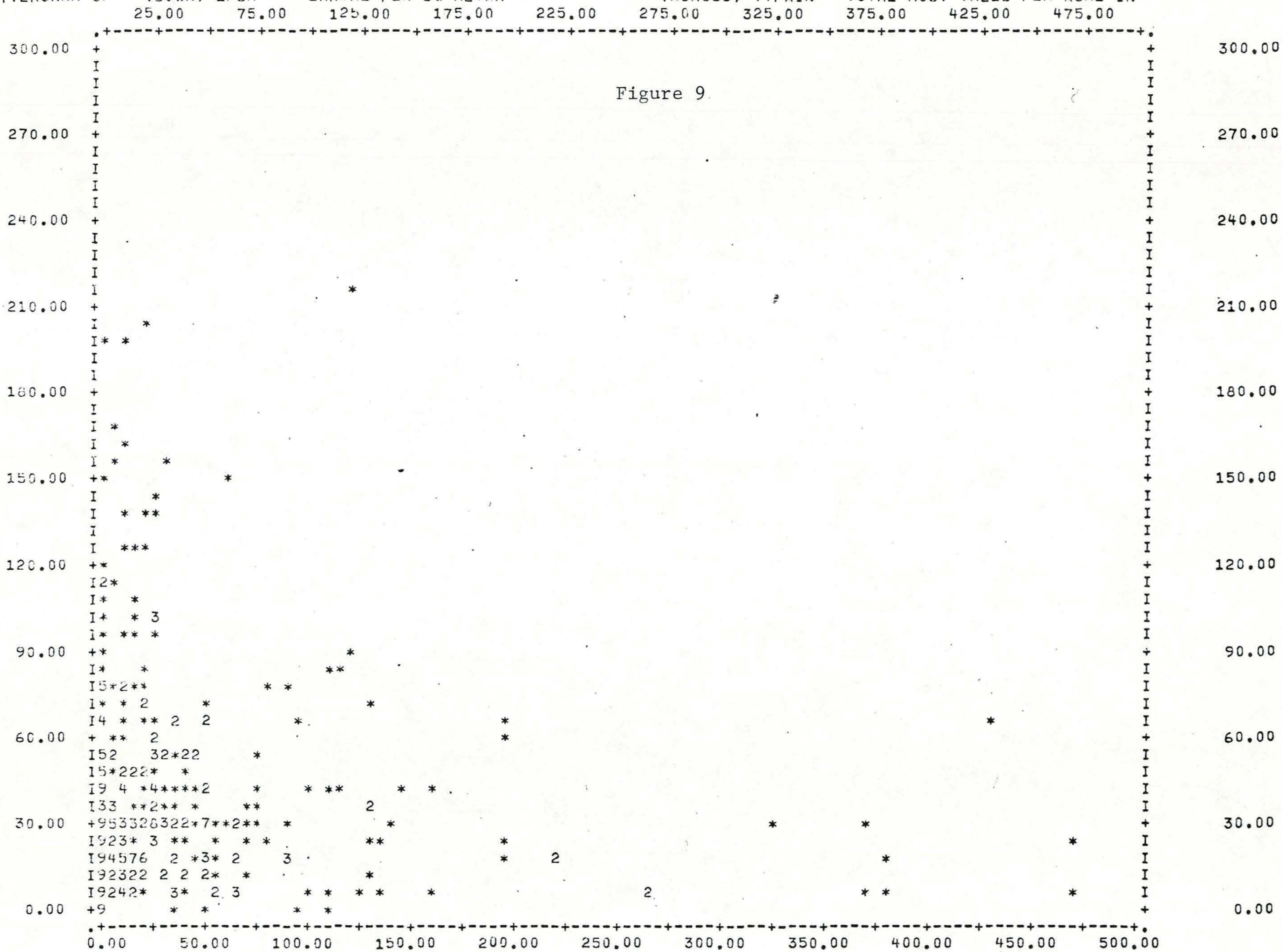
WSBW Instar II Dispersal and Stand Conditions

Spring dispersal of WSBW Instar II larvae was rather uniform over the conditions represented by our intensive stands and the Lubrecht site. In fact, there was no measurable effect of stand conditions on dispersal. Details of sampling for larval dispersal were given in a progress report by Fellin (1980). Sticky traps were uniformly distributed across the intensive stands; one trap was associated with each of our permanent regeneration plots. Traps also were placed in the adjacent, uncut stands; these were the controls. Trap data were used to compute larvae per meter^2 reaching the trap site.

Larvae per meter^2 were not related to total host trees per acre inside the cutting unit (fig. 9), total host basal area (fig. 10), or the ratio of host trees per acre inside the stand to host trees per acre in the adjacent stand. The same was true when total trees per acre was used as the independent variable. We thought that possibly the ratio of larvae per meter^2 inside the cut unit to the controls may be related to the ratio of trees per acre inside the cut unit to those in the adjacent stand. However, figure 11 shows this simply was not true.

FILE INTPLOT. (CREATION DATE = 03/09/82)
SCATTERGRAM OF (DOWN) LPSM LARVAE PER SQ METER (ACROSS) TTPAIN TOTAL HOST TREES PER ACRE IN

Figure 9



[redacted]TTE[redacted]UN [redacted]

FILE INTPLOT. (CREATION DATE = 03/09/82)
SCATTERGRAM OF (DOWN) LPSM LARVAE PER SQ METER (ACROSS) TBAPAIN TOTAL HOST BASAL AREA PER ACRE I

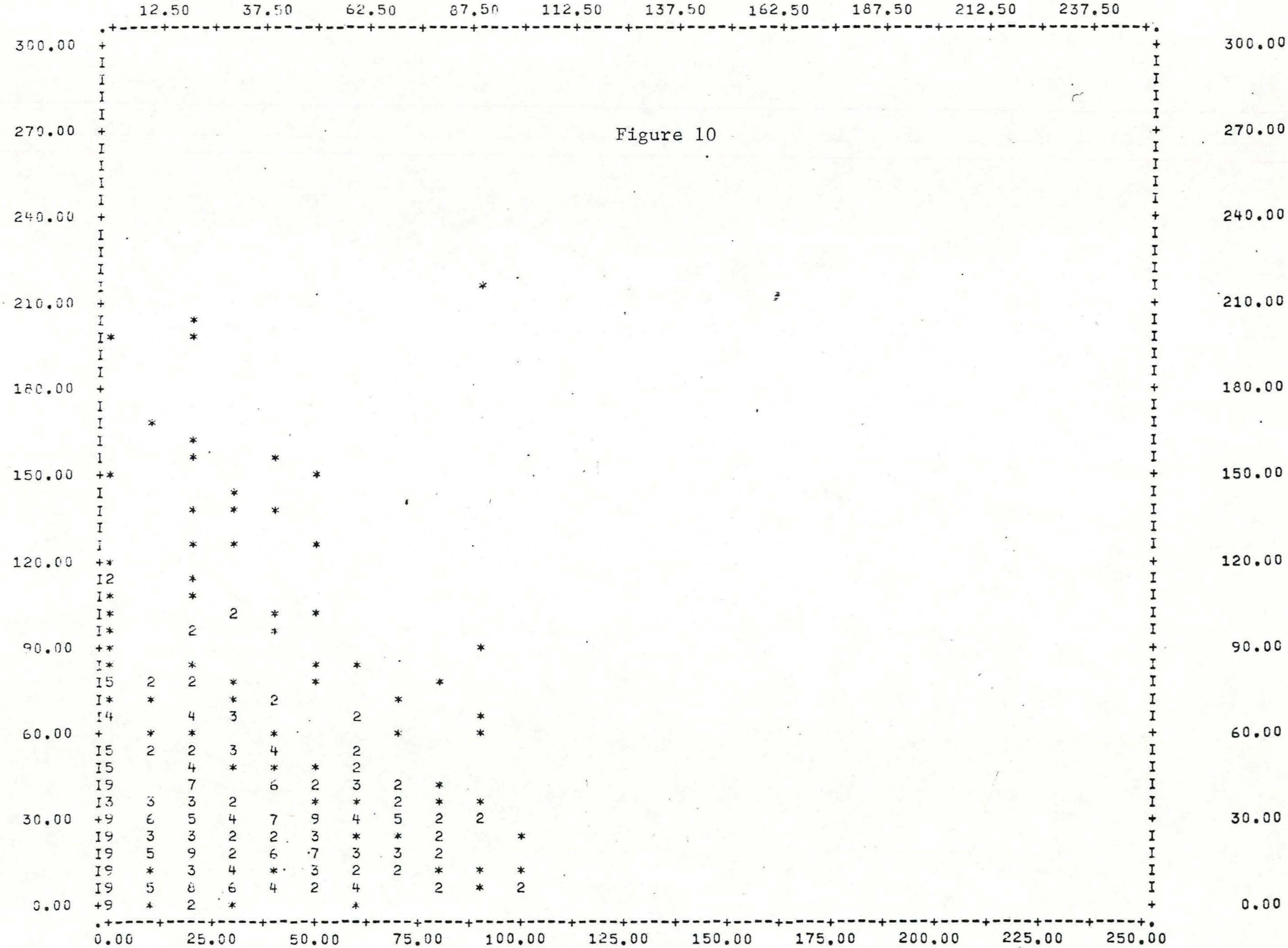


Figure 10

SCATTEST

FILE INTPLOT. (CREATION DATE = 03/09/82)

SCATTERGRAM OF (DOWN) RLPSM RATIO LPSM (ACROSS) RTPA RATIO TREES PER ACRE

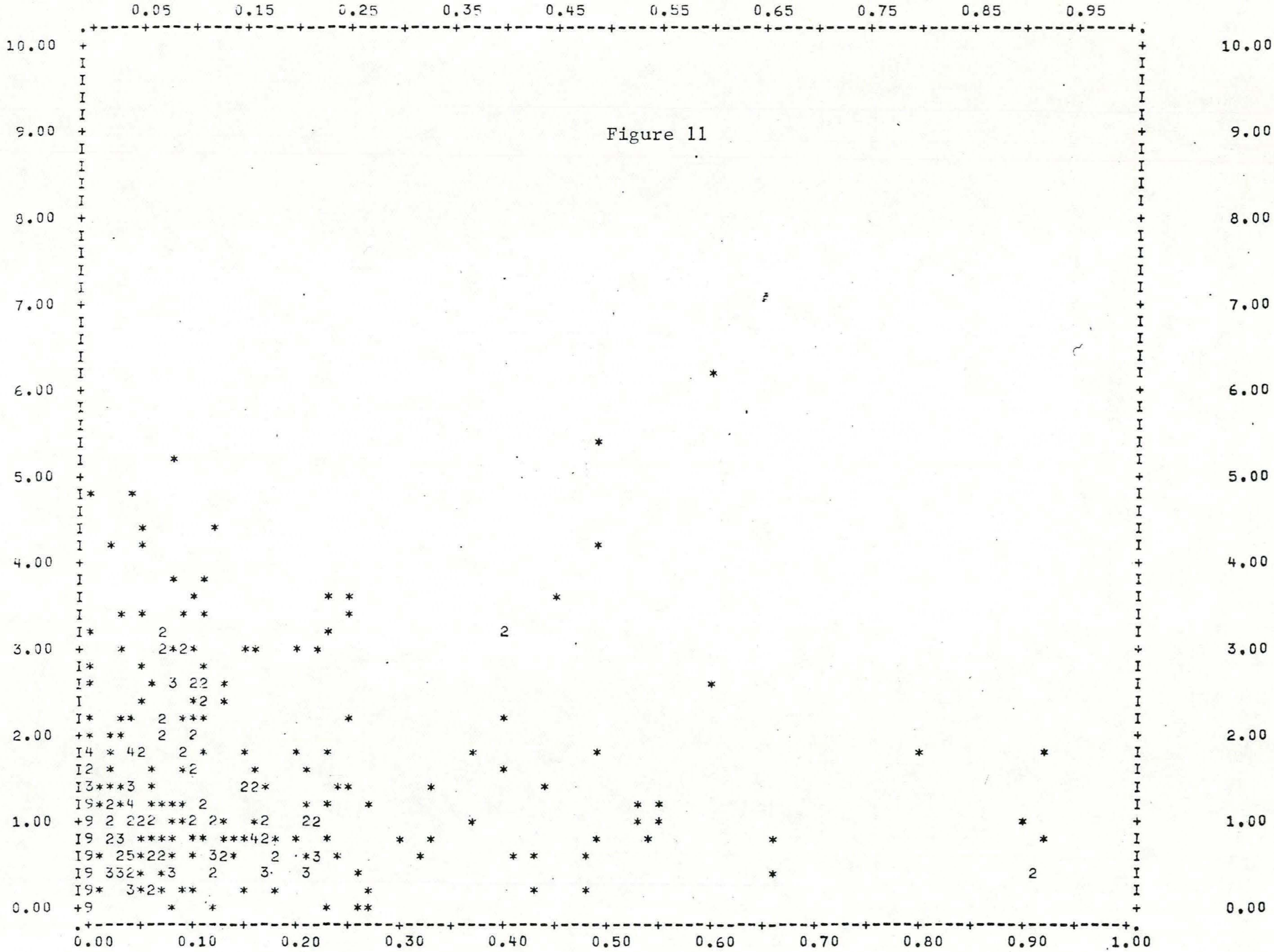


Figure 11

Larvae per meter^2 inside the cut stands were closely related to control values (fig. 12). The R^2 was 0.80 and slope of the computed regression line was 1.29, indicating that slightly more larvae were found inside the cut units than in the adjacent stands. Furthermore, there was no indication of an edge effect. Data were categorized as "edge" or "inside" (nonedge). A scattergram (fig. 13) clearly shows that edge traps do not receive more larvae than nonedge. Regression statistics are shown for all the larvae-stand relationships in table 6.

These results tend to support the hypothesis that the very small, lightweight Stage II larvae can be carried long distances by wind currents. It is possible that relatively even dispersal occurs throughout major drainages if the host substrate also is prevalent throughout the same area. Just how far the larvae are carried is not known. It could be from a few hundred yards to several miles or more. Our data cannot answer that question.

Possibly the control trap catches are biased downward because of larval interception by the denser stands in which the traps were placed. We don't know this; what we do know is that just as many larvae reach the forest floor in clearcuts, seed tree cuts, shelterwoods, and selection cuts, as reach the floor in uncut stands.

FILE MEANLPSM (CREATION DATE = 03/09/82)
SCATTERGRAM OF (DOWN) LPSMIN LARVAE PER SQ M INSIDE STAND (ACROSS) LPSMOUT LARVAE PER SQ M OUTSIDE STAND

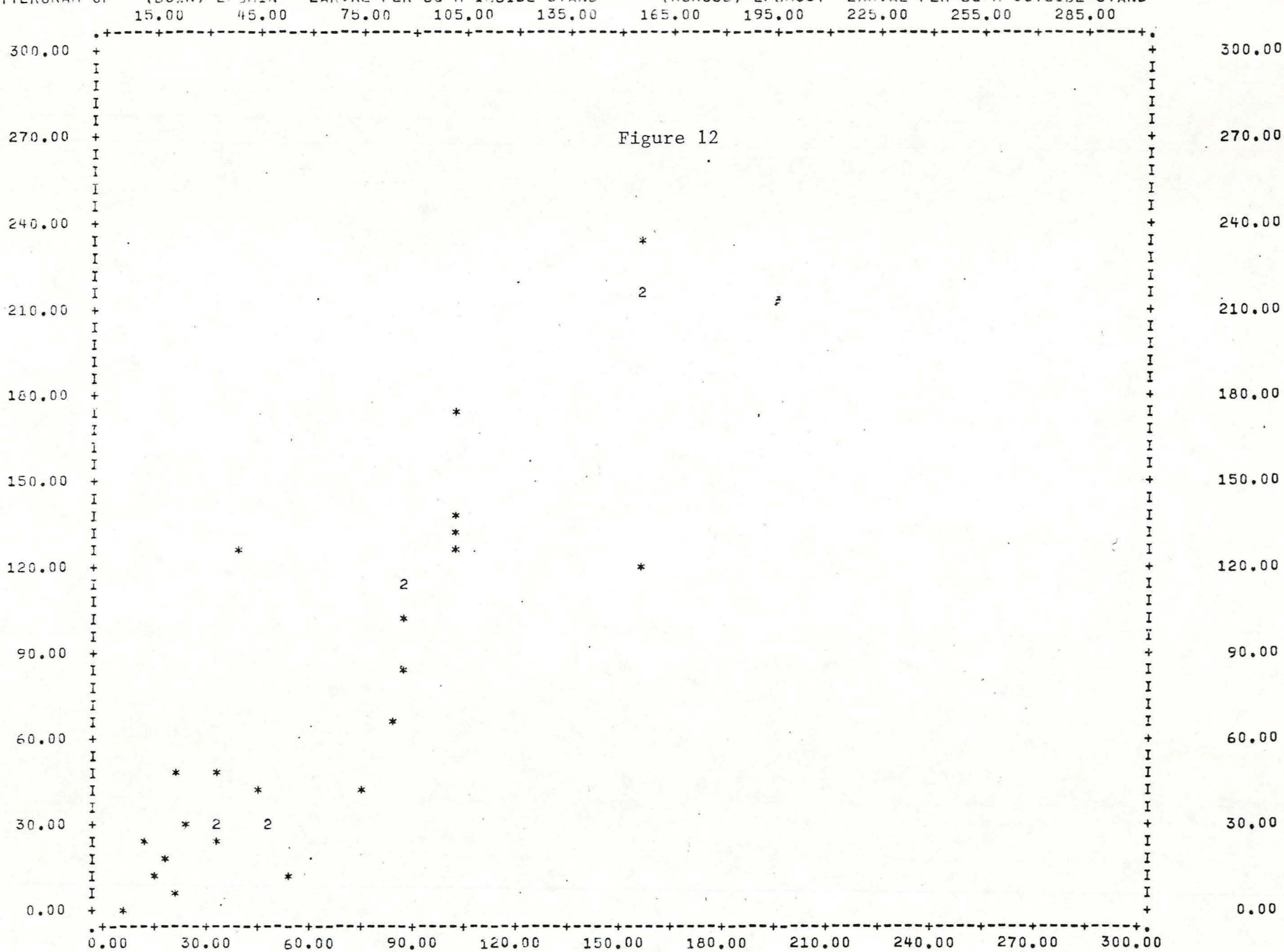


Figure 12

[redacted] EDGELPS [redacted]ON

FILE EDGELPSM (CREATION DATE = 03/23/82)
SCATTERGRAM OF (DOWN) INSIDE LARVAE PER SQ METER INSIDE TRAPS (ACROSS) EDGE LARVAE PER SQ METER EDGE TRAPS

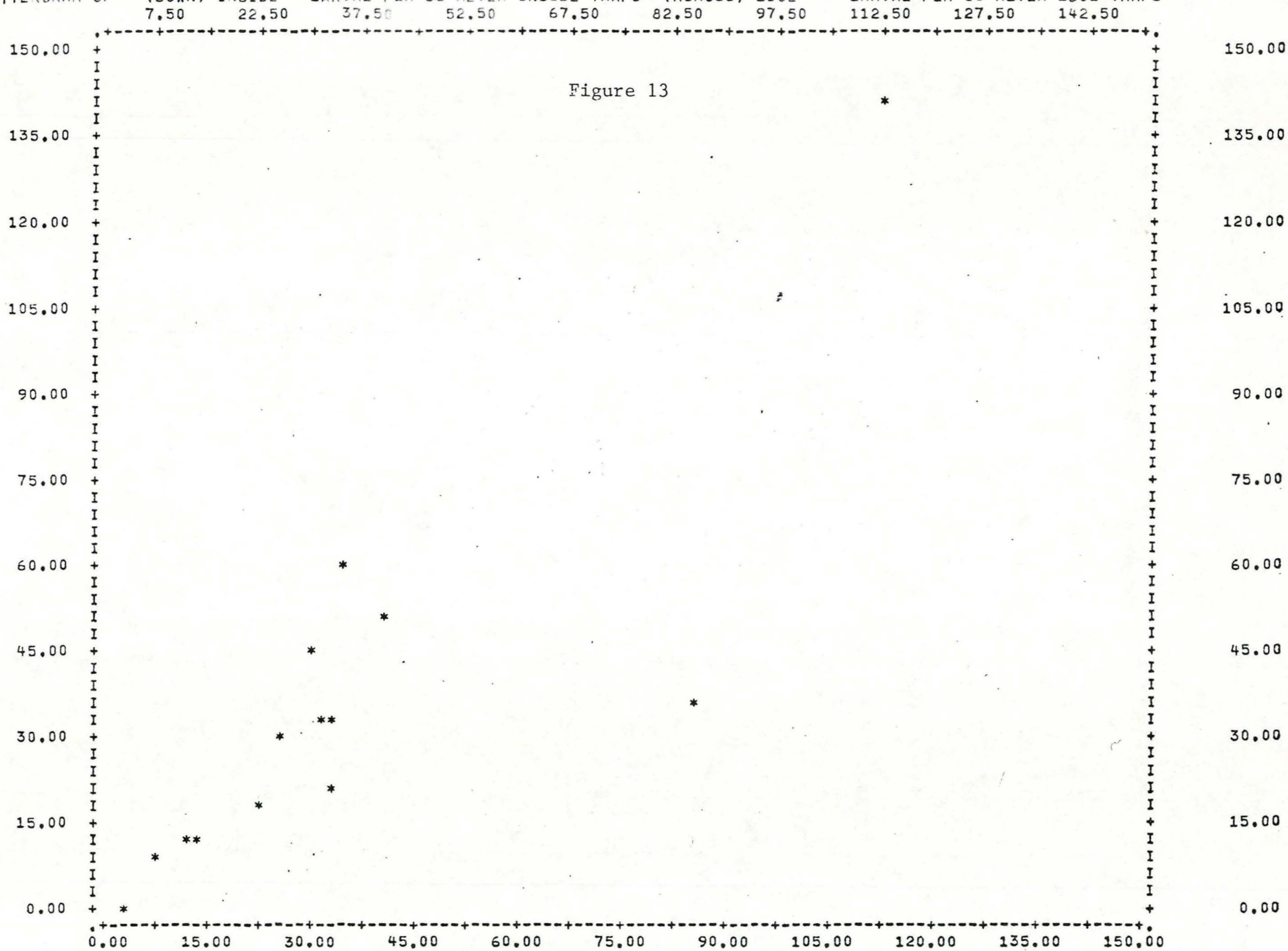


Figure 13

Table 6.--Regression statistics for several larval-stand relationships[1]

Dependent variable	Independent variable	Slope	Intercept	R^2	Significance
LPSM[2]	TTPAIN[3]	-0.0213	37.407	0.0016	0.2108
LPSM	TBAPAIN[4]	0.0782	34.099	0.0033	0.1175
LPSM	RTPA[5]	7.9574	36.003	0.0013	0.2366
LPSM	RTBA[6]	-3.8283	37.573	0.0010	0.2655
RLPSM[7]	TTPAIN	0.0020	1.0843	0.0161	0.0050
RLPSM	TBAPAIN	0.0158	0.7326	0.1553	0.0000
RLPSM	RTPA	1.2114	1.0303	0.0337	0.0001
RLPSM	RTBA	0.9574	0.8620	0.0723	0.0000
LPSMIN[8]	LPSMED[9]	0.9875	1.3897	0.7252	0.0001
LPSM	LPSMOUT[10]	1.2922	-6.9373	0.7960	0.0000

[1]These data were obtained from the intensive stands in which spring dispersal of second instar larvae was measured along with conifer stocking and growth.

[2]LPSM = larvae per meter^2 inside cut stand.

[3]TTPAIN = total host trees per acre inside cut stand. Includes Douglas-fir, grand fir, subalpine fir, Engelmann spruce, and western larch.

[4]TBAPAIN = total host basal area per acre inside cut stand.

[5]RTPA = Ratio of trees per acre inside cut stand to trees per acre in adjacent stand, all species.

[6]RTBA = Ratio of total basal area inside cut stand to total basal area in adjacent stand, all species.

[7]RLPSM = Ratio of larvae per meter^2 inside cut stand to larvae per meter^2 outside stand.

[8]LPSMIN = Larvae per meter^2 inside stand but not on stand edge.

[9]LPSMED = Larvae per meter^2 inside cut stand at stand edge.

[10]LPSMOUT = Larvae per meter^2 outside cut stand (controls).

WSBW Instar II Dispersal and Seedling Damage

Western spruce budworm defoliation on host seedlings within the "intensive" stands was not related to numbers of spring dispersing Stage II larvae, contrary to our expectations. A scattergram of percent current defoliation over larvae per meter^2 showed no pattern; low numbers of larvae were associated with both high and low levels of defoliation (fig. 14). Although this figure considers nonestablished, established, and management host seedlings, implying varying seedling sizes, the same sort of relationship was evident when the various seedling classes were considered separately. In any case, most of the defoliation was less than 30 percent and of little consequence to the seedlings. This strongly supports the situation in the "extensive" stands where only nominal seedling damage has been observed even though very obvious defoliation occurred in the adjacent stands.[9] Apparently the small larvae are extremely vulnerable to weather and predation when they happen to be deposited on small seedlings. Also, the "target area" is much reduced because of seedling size. Furthermore, a seedling is not a sticky trap. Nevertheless, one would expect that as the density of dispersing larvae increased, an increase in seedling defoliation would occur; as noted before, this was not the case.

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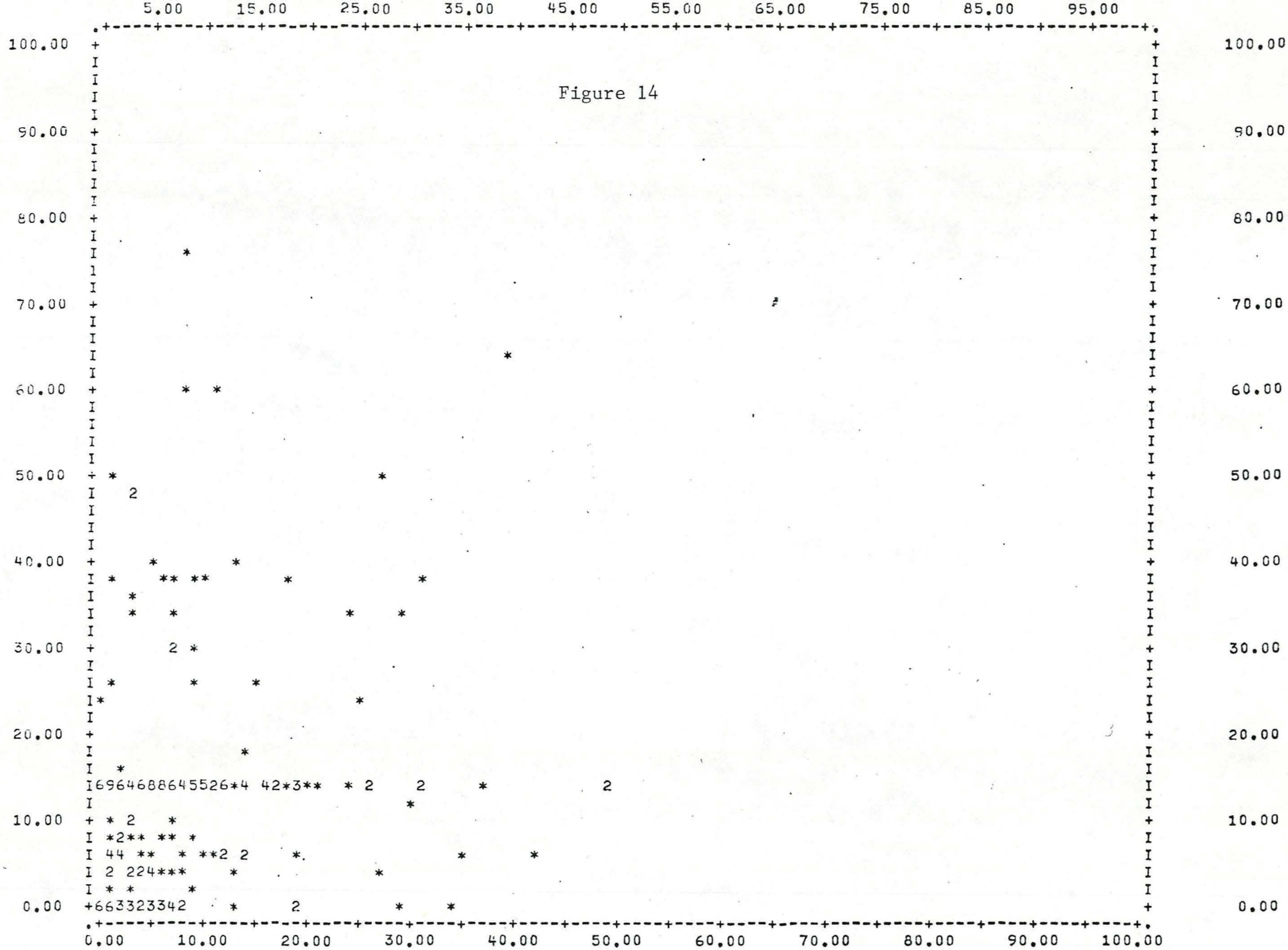
[9]Data are currently under analysis.

[redacted]

FILE MGTCP2.A (CREATION DATE = 02/23/82)
SCATTERGRAM OF (DOWN) CDHOST MEAN CURRENT DAMAGE HOST SPP (ACROSS) LARVAE



Status of 1981 Data

Fieldwork in 1981 was concentrated in the grand fir forest climax series, according to our original proposal. Thirty-nine new stands were sampled and all seven intensive sites were remeasured. All data, including: (1) regeneration, (2) adjacent stand, (3) increment core, and (4) larvae and defoliation have been keypunched, entered on disk and tape files, and edited. These files are now maintained on the Forest Service Perkin-Elmer Computer located at the Northern Forest Fire Laboratory in Missoula, Montana.

During 1981 we finished a series of FORTRAN programs designed to integrate our various data sets. This done, all data collected through 1981 are being analyzed. Data from 1979, 1980, and 1981 were used in developing the probability of stocking and stand vulnerability models, as well as in the analysis of larval dispersal. In short, we are right on schedule!

CONCLUSIONS AND RECOMMENDATIONS

Our analyses are continuing, so conclusions at this point in time are still rather tentative. Nevertheless, the following can be stated:

1. Probability of stocking with natural regeneration is reduced in dry Douglas-fir, dry subalpine fir, and moderate subalpine fir habitat type groups. Apparently this is due to reduced cone and seed supply in habitats that regenerate primarily to WSBW host species.

2. Vulnerability of stands to WSBW attack is somewhat predictable. Dry Douglas-fir habitats on steeper slopes with a predominance of the stand in host basal area are most vulnerable; wetter, colder habitats are least vulnerable.

3. WSBW spring dispersal of Stage II larvae does not appear to be related to local stand conditions. Dispersal is relatively uniform and equal between and within cut and uncut stands.

4. Seedling defoliation by WSBW is only weakly dependent on larval dispersal. Defoliation of seedlings in previously cut stands generally is quite low, irrespective of the number of larvae reaching the target area or the defoliation intensity in the adjacent stands.

Our recommendations for silvicultural treatment to reduce stand susceptibility and vulnerability to WSBW have not changed since our 1981 progress report to CANUSA. Looking ahead, and based on data from past harvest cuts, it certainly appears possible to utilize silvicultural techniques to reduce the impact of WSBW on establishment and growth of conifer stands. The following suggestions are merely a beginning look at what we can do. It is first understood that in any harvest cut (or others, such as thinning, etc.), the basic ecological criteria for seedling establishment and growth, exclusive of WSBW considerations, must first be met. Within those restrictions, the following ideas appear valid:

1. Reduce the ratio of host:nonhost basal area. In partial cuts, favor the nonhost species.

2. Remove residual host overstory from partial cuts no later than 10 years following establishment of regeneration.

3. For partial cuts, minimize the residual host basal area left either for seed source or shelter.

4. Create a "buffer" by reducing basal area of host species in adjacent stand within 100 meters of the boundary of the adjacent stand.

5. Make cutting units as large as possible commensurate with other management restrictions.

6. When planting, prescribe a good mix of species, but no more than one-third host seedlings.

7. During stand development, maintain the minimum number of seedlings-per-acre/basal area relative to other management objectives, and maintain a minimum ratio of host:nonhost growing stock (1:3 or 1:4).

These actions, if and when invoked over large enough land bases (subcompartment, for example), may influence adult and larval WSBW dispersal, will limit population size, and will significantly reduce present and current WSBW impact on stands managed for fiber production.

WORK REMAINING ON STUDY

This study was originally designed to study WSBW relationships in four silvicultural systems over the three major forest climax series found in western Montana. We were funded for FY 1982 to collect similar data in subalpine fir stands in eastern Montana and this work will be done this summer. All data have been collected in the three forest series in western Montana and are now being analyzed. Eastern Montana data will be collected this summer; at this time candidate stands have been selected. Data analysis and hypothesis testing are ongoing. Fiscal year 1983 will be entirely devoted to final data analysis and report writing.

COOPERATION AND COORDINATION

We continue to cooperate with the Moscow Forestry Sciences Laboratory, with Region 1 Forest Pest Management and Region 1 Timber Management, and with the Bureau of Land Management and Bureau of Indian Affairs. Dennis Ferguson of Moscow, and Bill Wulf of Region 1, continue to be particularly cooperative.

PROBLEMS ENCOUNTERED

No significant problems were encountered. Our research is progressing on schedule.

MANUSCRIPTS OR REPORTS PREPARED OR PLANNED

Manuscripts in press

Carlson, C. E., and W. McCaughey.

1982. Radial increment analysis to index past western spruce budworm activity in western Montana. USDA For. Serv. Res. Pap. INT-291.

Manuscripts in preparation

Carlson, C. E., L. Theroux, W. McCaughey, and W. Schmidt.

1983. Influence of western spruce budworm on stocking probabilities in western Montana.

Papers presented

Carlson, C. E., and L. Theroux.

1982. Predicting intensity of western spruce budworm radial growth reduction in western Montana forests. Abstract, 55th Ann. Northwest Scientific Association, March 1982.

Carlson, C. E.

1982. Current developments in research concerning budworm-stand relationships in western Montana. Panel presentation, 33rd Western International Forest Work Conference, Missoula, MT.

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Carlson, C. E., and W. McCaughey.

[In press] Radial increment analysis to index past western spruce budworm, *Choristoneura occidentalis* Freeman, activity in western Montana. USDA For. Serv. Res. Pap. INT-291. Intermountain For. and Range Exp. Stn., Ogden, Utah.

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APPENDIX

Habitat Type Groupings for 1979, 1980, and 1981 data[1]

GROUP 1 (Dry Douglas-fir)

Habitat code	Type name[2]
10	Scree
210	PSME/AGSP
230	PSME/FESC
261	PSME/PHMA-PHMA
262	PSME/PHMA-CARU
311	PSME/SYAL-AGSP
312	PSME/SYAL-CARU
313	PSME/SYAL-SYAL
360	PSME/JUCO
350	PSME/ARUV
Total types 10	Total plots 592

GROUP 2 (Moist Douglas-fir)

Habitat code	Type name[2]
250	PSME/VACA
281	PSME/VAGL-VAGL
282	PSME/VAGL-ARUV
283	PSME/VAGL-XETE
291	PSME/LIBO-SYAL
292	PSME/LIBO-CARU
293	PSME/LIBO-VAGL
321	PSME/CARU-AGSP
322	PSME/CARU-ARUV
323	PSME/CARU-CARU
324	PSME/CARU-PIPO
330	PSME/CAGE
340	PSME/SPBE
Total types 13	Total plots 450

GROUP 3 (Dry suablpine fir)

Habitat code	Type name[2]
690	ABLA/XETE
691	ABLA/XETE-VAGL
692	ABLA/XETE-VASC
792	ABLA/CAGE-PSME
Total types 4	Total plots 353

GROUP 4 (Warm & moist subalpine fir, grand fir, and cedar

Habitat code	Type name[2]
440	PICEA/GATR
510	ABGR/XETE
520	ABGR/CLUN
521	ABGR/CLUN-CLUN
522	ABGR/CLUN-ARNU
523	ABGR/CLUN-XETE
530	THPL.CLUN
531	THPL/CLUN-CLUN
532	THPL/CLUN-ARNU
533	THPL/CLUN-MEFE
591	ABGR/LIBO-LIBO
592	ABGR/LIBO-XETE
571	TSHE/CLUN-CLUN
572	TSHE/CLUN-ARNU
621	ABLE/CLUN-CLUN
622	ABLA/CLUN-ARNU
623	ABLA/CLUN-VACA
624	ABLA/CLUN-XETE
625	ABLA/CLUN-MEFE
630	ABLA/GATR
640	ABLA/VACA
Total types 21	Total plots 726

GROUP 5 (Moderate subalpine fir)

Habitat code	Type name[2]
653	ABLA/GATR
661	ABLA/LIBO-LIBO
662	ABLA/LIBO-XETE
663	ABLA/LIBO-VASC
720	ABLA/VAGL
731	ABLA/VASC-CARU
750	ABLA-CARU
Total types 7	Total plots 173

GROUP 6

Habitat code	Type name[2]
670	ABLA/MEFE
680	TSME/MEFE
740	ABLA/ALSI
Total types 3	Total plots 183

[1]Partially based on personal communication with Dr. Robert Pfister in 1980.

[2]From "Forest Habitat Types of Montana" by Robert Pfister and others. INT GTR-34, 1977.